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Second Military Antifreeze Recycling Study

May 1994

By **Dwayne Davis**
USA Tank Automotive Command
Mobility Technology Center Belvoir

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Four commercial used antifreeze recycling systems are tested with used MIL-A-46153 antifreeze. Evaluation consisted of performing standard engine coolant on recycled antifreeze recovered from each recycling system. Successful systems were accepted for military use.

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Table of Contents

Section I
Background/Objective

One of the Army's first attempts to successfully recycle used engine antifreeze was during the second World War. After the U.S. entered the war, shortages of Ethylene Glycol (EG) feedstocks used to manufacture antifreeze prompted U.S. Army officials to consider ways to conserve antifreeze. A study on antifreezes for military vehicles was conducted by the Office of the Chief of Ordnance, U.S. Army, and was completed July 1944.[1] The study examined chemical treatment/filtration, distillation, and a third method involving reinhibition of used antifreeze. The first two were precluded as impractical methods due to logistic problems. The third method of reinhibiting fairly clean used antifreeze was determined to be the most viable method.

Recycling used antifreeze was reexamined in 1976 by the U.S. Army Mobility Equipment, Research and Development Command (MERADCOM) at the height of the energy crisis.[2] As during WWII, a shortage of antifreeze was brought about because of a shortage of EG feedstocks. In response, the Army began the MERADCOM study to determine the feasibility of reclaiming used antifreeze. The 1976 study examined three major recycling methods. They included filtration followed with reinhibition, filtration followed with ion exchange and reinhibition, and distillation. Other methods examined consisted of filtration coupled with precipitation employing calcium hydroxide and barium chloride as flocculating agents. Distillation was again eliminated as a workable method, but this time because of the possible damaging environmental effects disposal of the residual waste could cause. From the remaining methods, filtration followed with reinhibition was chosen as the most economical and practical method. This lead to the development of the currently used military specification MIL-A-53009,[3] liquid cooling systems, antifreeze extender additive. The use of MIL-A-53009 is similar to the practice developed during WWII. For example, depending on its condition after the recommended three year usage limit, the used antifreeze is reinhibited with MIL-A-53009 for one year additional service.

The U.S. Army once again considered used antifreeze recycling in 1989 through a collaborative endeavor with the U.S. Air Force (USAF). In the U.S. Army Belvoir Research, Development, and Engineering Center (BRDEC) report,[4] the USAF and BRDEC examined three commercial recycling systems which incorporated methods identical to those considered in the 1976 MERADCOM report. For example,

precipitation/filtration followed with reinhibition and filtration followed with reinhibition. Each system was portable and designed for on-site use. The results of the study were indeterminate as to the effectiveness of the systems because the used antifreeze recycled was not degraded enough to test the clean-up capability of the systems. However, the findings were sufficiently positive to warrant a second BRDEC recycling study where more controls could be imposed.

The objective of the present study, as in the previous studies, is to find plausible used antifreeze recycling methods suitable for use with military antifreeze, MIL-A-46153,[5] the standard for all DOD heavy-duty ground vehicles and equipment. On-site systems are distinguished from companies offering pick-up and delivery services which process used antifreeze off-site. In addition to determining which systems and methods are effective, policies and guidelines governing the testing and the use of recycling systems will be established.

Each recycler manufacturer in this study stated at the onset that their system could effectively process most if not all commercially available antifreezes, including heavy-duty and light-duty types. However, the differences between military antifreeze and commercial antifreeze usage practices required this study's emphasis on used MIL-A-46153. All quality automotive engine antifreezes contain buffers to help reduce the deleterious effects of acids, which form in an antifreeze during normal use. MIL-A-46153 has been formulated with a higher buffering capacity than most commercial antifreezes to extend its useful life. This large buffering ability is sometimes completely retained in the used antifreeze even after two years of use because of the limited use heavy-duty combat/tactical vehicles receive compared to equivalent, heavy-duty commercial vehicles. For example, it is estimated that the highest mileage a tactical truck or combat vehicle will receive in one year is less than 30,000 miles. This compared to commercial on-highway, heavy-duty trucks which on average accumulate 120,000 to 180,000 miles a year.[6] This retained buffer may reduce the effectiveness of the recycling systems.

In addition to MIL-A-46153's buffer affecting recycler system efficiency, the formulation of MIL-A-46153 may be incompatible with the individual recycling system's inhibitor packages used to restore the recycled antifreeze to an acceptable performance level. For example, when two incompatible antifreezes are combined, a number of problems can occur, all of which cause engine over-heating and permanent engine damage. Problems such as radiator tube blockage, water pump leakage, reduced heat transfer, and increased corrosion, all can occur. Also, each prospective systems' inhibitor package and resultant recycled product needs to be compatible with MIL-A-46153 antifreeze in order that admixing of new and recycled antifreeze can be performed safely without damaging vehicles or equipment.

Section II
Approach

To evaluate on-site recyclers, four systems were chosen. The four systems represented the prevailing recycling methods available within the marketplace at the time this study was began in October 1990. The methods included distillation, ion exchange, ultra-filtration, and chemical pretreatment followed by filtration. The manufacturers respectively were Finish-Thompson Incorporated (FTI), BG Products Incorporated (BG), the Kleer-Flo Company (KFC), and the FPPF Chemical Company (FPPF).

The examination of each system consisted of conducting laboratory tests on recycled antifreeze samples collected from each system. The BG, FTI, and FPPF systems were operated by an employee of the Center. The KFC system was operated at the manufacturer's facility, by KFC employees, under a Center employee's supervision. A recycled sample was generated from the individual systems by recycling a batch of used antifreeze, taken from common stockpile of "reference" used MIL-A-46153 antifreeze. A common stockpile was employed to insure that each system was equally tested. A total of thirteen 55-gallon drums of used MIL-A-46153 were obtained from Fort Bliss, Texas, Anniston Army Depot, Alabama, and Letterkenny Army Depot, Pennsylvania. The used MIL-A-46153 was recovered from several heavy-duty tactical vehicles, including 2-1/2-ton trucks, 5-ton trucks, construction equipment, etc., all representing heavy-duty vehicle operation. The individual drainings were in service a minimum of one year. Of the 13 drums, 6 from Anniston and 1 from Letterkenny were selected to produce a "reference" used MIL-A-46153 with contaminated appearance, low pH, and low Reserve Alkalinity (RA). The contents of the 7 drums were emptied into a large fiberglass tank. The resultant solution was tested and found to have good corrosion protection as determined by the glassware corrosion test (ASTM D-1384). To render the reference's condition more reflective of a used antifreeze that had to be drained and insure a rigorous examination, degradation contaminants commonly found in used antifreeze were added. The contaminants included glycolic acid, formic acid, glyoxal, and formaldehyde. The contaminants were added in quantities so that the final solution contained acid and aldehyde concentrations simulating those experimentally found in used MIL-A-46153.[7] For a description of the used "reference" MIL-A-46153, see Table 1.

Table 1. Reference Used MIL-A-46153

CONTAMINANTS AND QUANTITY ADDED

Glycolic acid, pure crystals	=	3,409 grams
Formaldehyde solution, 37% (w/w)	=	620 grams
Formic acid, 88%	=	465 grams
Glyoxal, 40% in water	=	310 grams

	BEFORE CONTAMINANTS	AFTER CONTAMINANTS
pH	7.5	7.2
RA	11.7mL	7.4mL
Freeze Pt	-25°F	-25°F

APPEARANCE OF REFERENCE USED MIL-A-46153

Blue-green color, slightly turbid in appearance with moderate amounts of debris (i.e., dirt, leaves, dead insects, etc) present. Light-brown, flocculent precipitate floats on surface and settles on the bottom of containers. Precipitate is a combination of contaminant engine oil and precipitated phosphate inhibitor. The precipitate, iron phosphate, is the result of MIL-A-46153's trisodium phosphate inhibitor combining with iron accumulated in the antifreeze during normal use. Ethylene glycol odor mingled with a very subtle egg odor. The appearance of the used antifreeze was the same both before and after the degradation products added.

Laboratory antifreeze tests from the American Society for Testing and Materials (ASTM), 1988 Annual Book of Standards (vol 15.05), along with non-ASTM test methods were used to determine the overall condition of the recycled antifreeze. Specifically, the tests conducted measured the performance and quality of the recycled antifreezes. Each system's effectiveness was determined using the results of the tests. Those system's whose recycled antifreeze met the ASTM and non-ASTM test requirements were deemed acceptable for military use. The two categories of tests included the following:

PERFORMANCE TESTS

- Foaming Tendencies of Coolants in Glassware (ASTM D-1881)
- Corrosion Test for Engine Coolants in Glassware (ASTM D-1384)
- Cavitation Erosion-Corrosion of Aluminum Pumps with Engine Coolants (ASTM D-2809)
- Simulated Service Corrosion Testing of Engine Coolants (ASTM D-2570)

QUALITY TESTS

- Ash Content of Engine Coolants and Antirust (ASTM D-1119)
- Reserve Alkalinity (RA) of Engine Antifreeze, Antirusts, and Coolants (ASTM D-1121)
- pH of Engine Antifreezes, Antirusts, and Coolants (ASTM D-1287)
- Use of The Refractometer for Determining the Freezing Point of Aqueous Engine Coolants (ASTM D-3321)
- Trace Chloride Ion in Engine Coolants (ASTM D-3634)
- Metal Content Using ICP/Flame Spectroscopy (non-ASTM)
- Total Dissolved Solids by Conductivity Meter (non-ASTM)

Most of the ASTM tests for engine antifreezes are designed to examine new antifreeze concentrate before it is diluted with water. For the majority of tests conducted in this study, test samples were tested as is (i.e., without further dilution). Some tests did require dilution of the test sample to preserve the test's original significance and severity. For example, the foam test, the glassware corrosion test, and the water pump cavitation-erosion test (D-2809). The samples for these tests were diluted with the distilled water and corrosive salts to obtain test samples resembling those described in the test method.

The freeze points of the recycled samples were measured using a hand-held field refractometer as prescribed in the ASTM D-3321 test method. The freeze point data were used to help adjust the recycled antifreeze to approximately 50/50 mixtures (e.g., -34°F 50/50 antifreeze). The remaining quality tests were conducted to help characterize the physical and chemical condition of the recycled antifreeze. Some of these tests are used as quality control tests to determine if a new antifreeze has been properly blended. For example, the RA test (D-1287) and pH test (D-1121) measure an antifreeze's approximate buffering capacity. In general buffered antifreezes which are slightly to moderately alkaline (i.e., pH between 7.5 and 9, RA above 8mL) help decrease corrosion rates of most metals found in engine cooling systems. The ash content (D-1119) is determined by measuring the amount of residue that remains after an antifreeze has been ignited. The less volatile corrosion inhibitors found in the antifreeze are the major constituents of the ash. However, the ash content is not a good measure of the total inhibitor concentration because of other more volatile inhibitors which are lost after ignition. The ash content is included in this series of tests to help assess general quality of the recycle samples. An excessive ash level (i.e., above 2%) would indicate an over inhibited recycled antifreeze.

The non-ASTM test for Total Dissolved Solids (TDS) by conductivity is another general property test. Conductivity of an antifreeze correlates to the amount of TDS. More specifically, conductivity is a gauge of an antifreeze's capacity to conduct an electric current.[8] In general, a large conductivity reading indicates a more conductive solution and a high TDS level. Like the ash test, the TDS test can be used to check for gross over inhibition of a recycled antifreeze. In addition, a large conductivity reading for a recycled antifreeze may also indicate the presence of excessive dissolved contaminants, such as organic acids and metals, not removed by the recycling process.

The performance tests were conducted to determine those recycled antifreezes which may cause corrosion problems during operation. For example, the foam test (D-1881) was conducted to determine those recycled antifreezes which may foam excessively during operation. Excessive foaming can result in poor heat transfer, reduced water pump efficiency, and loss of coolant. These actions all can result in engine overheating. The glassware corrosion test (D-1384) and the simulated service test (D-2570) were both used to determine those recycled antifreezes which will give poor general metal corrosion protection during vehicle operation. The simulated service test gives more discerning and definitive test results when compared to the glassware corrosion test. The improvement is obtained because actual automotive cooling system components are used in the test apparatus. The water pump cavitation erosion test (D-2809) distinguishes between antifreezes that contribute to cavitation erosion-corrosion of aluminum water pumps. It is also a more selective test than the glassware test because of its use of actual cooling system components. For example, an aluminum water pump is used in the test apparatus.

Section III
Testing

THE KLEER-FLO COMPANY (KFC) SYSTEM

A schematic of the Kleer-Flo AF250 unit examined is shown in Figure 1. The unit recycles used antifreeze in 25-gallon batches using "ultra-filtration" at a rate of 6 gallons/hour. The used antifreeze is first placed in a "dirty" reservoir located inside the recycler. The system is then started and the old antifreeze is passed through a series of filters which remove impurities at the molecular size level (i.e., 0.0025 microns). The recycled antifreeze is recovered with the same water/EG ratio as the original used antifreeze because very little water or EG is lost during the recycling operation. The recycled antifreeze is automatically transferred to a "clean" reservoir also inside the unit where the solution is reinhibited with a KFC inhibitor package and ready for use.

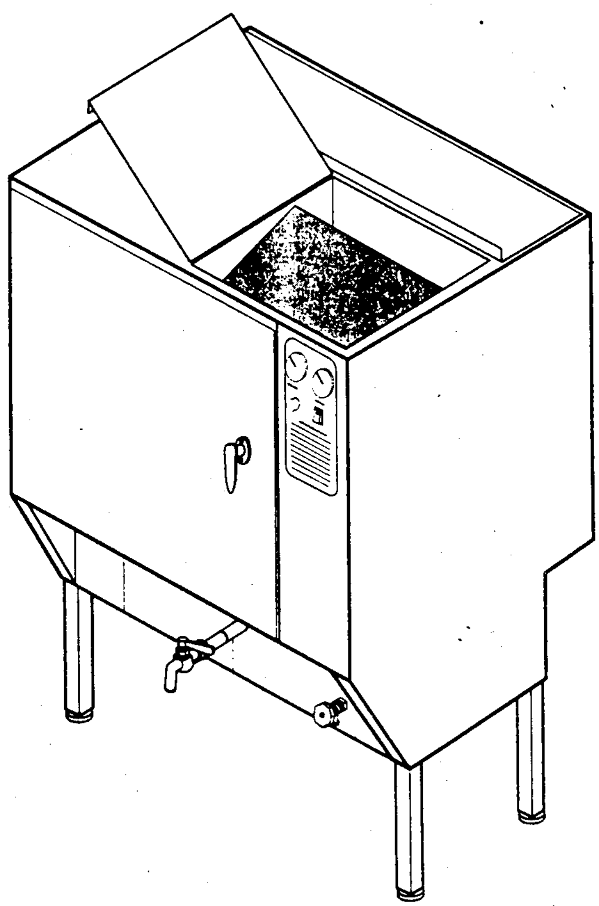


Figure 1. Kleer-Flo AF250 Unit

KFC offered two recycling methods with this ultra-filtration system. The first method incorporated ultra-filtration followed by reinhibition with a proprietary inhibitor package as aforementioned. The second KFC method combined the ultra-filtration system with a chemical pretreatment process. The pretreatment chemicals are added to the used antifreeze before filtration. The chemicals flocculate and coagulate dissolved contaminants into buoyant, clay-like amphorous solids. The majority of the solids are then skimmed from the solution's surface using a small, hand-held strainer. The remaining smaller particles are removed by the ultra-filtration system. The filtered solution is then reinhibited with KFC proprietary inhibitors. Water or new antifreeze concentrate is added to obtain the desired freeze protection.

For both KFC methods, the ultra-filtration system was very effective in removing insoluble contaminants (i.e., dirt, dead insects, leaves, etc.), producing a extremely clean looking product prior to reinhibition. The removal of contaminant metals was very thorough (see Table 4). However, upon reinhibition, each method's reinhibitor package produced a precipitate in the recycled antifreeze. For the ultra-filtration method, the recycled antifreeze appeared blue-green and slightly turbid in appearance. Moderate amounts of a fine white, granular precipitate was observed on the bottom of the sample container. No debris was present, but a subtle egg odor was detected. The precipitate was attributed to inhibitor saturation caused by the combination of the old inhibitors present in the reference used MIL-A-46153 and the new inhibitors added by the reinhibition procedure. The pretreatment method produced a recycled product similar to the ultra-filtration method sample, but without the egg odor. In addition, the white precipitate observed was in much greater abundance, and flocculent in appearance. This apparent incompatibility of the KFC inhibitors with used MIL-A-46153 (i.e., the presence of the precipitates) warranted nonacceptance of either KFC method for use with the military MIL-A-46153 antifreeze. After a brief investigation, KFC scientists attributed the precipitate to an unexpected reaction between the use MIL-A-46153 residual borax buffer and the flocculating agents in the pretreatment solutions. Once the apparent inhibitor problems of the KFC samples were observed, testing was limited to those shown in Tables 2, 3, and 4. Because of the aforementioned reinhibitor problems, nonacceptance of the KFC system will remain in effect until the system is modified to obtain compatibility with used MIL-A-46153.

THE FINISH-THOMPSON INC. (FTI) SYSTEM

A schematic of the FTI BE-15 unit examined is shown in Figure 2. The FTI system employs distillation to recycle used antifreeze. Simple (i.e., atmospheric) distillation is first used to remove the water from the spent antifreeze. This is followed by

vacuum distillation to remove the remaining EG. The used antifreeze is poured into the unit's 15-gallon process tank. The tank must be full before the unit will begin operation. Actual distillation begins approximately three to four hours after turning the unit on and takes a total of 12 to 15 hours to process a 15-gallon batch at the rate of 1 gallon/hour. The recovered water and the EG are collected in separate containers. The water and EG are not pure, but solutions with each acting as contaminant of the other. For example, the recovered water solution actually contains 3% EG by volume and the recovered EG solution is only 86% EG and 14% water by volume. The water and EG solutions are recombined to obtain a desired freeze protection. The final solution is then reinhibited with a FTI proprietary inhibitor package and ready for use.

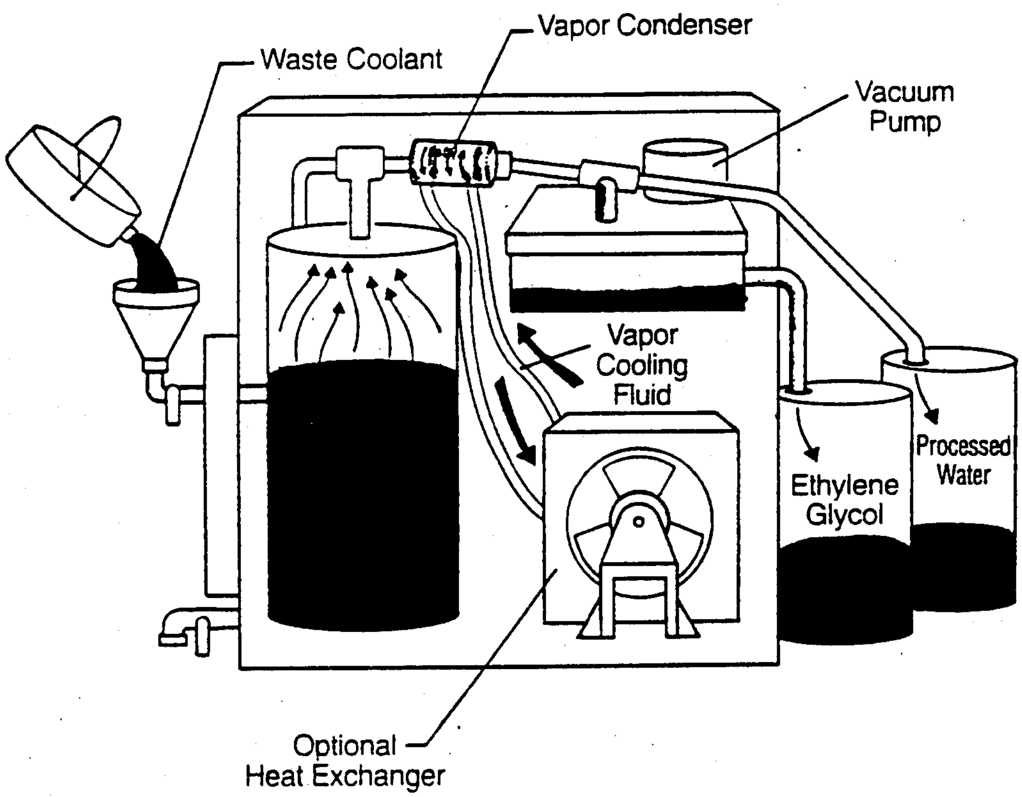


Figure 2. FTI BE-15 Unit

The FTI unit was operated a total of seven times. After the first recycling run, both the recovered water and recovered EG had a yellow tinge and significant amounts of a fibrous material floating on the surfaces and suspended throughout the upper portion of the sample vessels. A subtle rotten egg odor and debris (i.e., leaves, dead dead insects, etc.) were also noticed in the recovered EG. After these observations, a FTI representative was immediately contacted. The representative stated that the fibrous material had been observed in a previous examination of the FTI system and was

attributed to the organic dyes used in antifreezes. Because of its virtual non-volatile nature of the dyes, they are "carried over" during distillation. The representative also stated that the fibrous residuals would not affect the recycled product's performance. To help remove the other debris, the representative suggested that an antifoam agent, available with the system, be added to the unit prior to recycling. The antifoam agent was not used during the first run. The antifoam agent is not always needed depending on the initial cleanliness of the used antifreeze. The antifoam agent is used to help reduce "bumping" during distillation and thereby reduce the carry over of visible contaminants.

After the second and third run failed to improve the sample's appearance, the representative suggested that tap water only be recycled for the fourth run to clean the unit. The representative stated that the unit was a demonstration model and may have contained contaminants from past use. For the fifth run only, the EG from the previous runs was distilled and some improvement was noticed. For the sixth and seventh run, the EG and water were recombined. After the seventh run, both the recovered water and EG were much cleaner in appearance. The subtle rotten egg odor was still noticeable, but no fibrous material, debris, or yellow tinge was observed. Analysis of this final solution showed that the FTI system was fairly effective in removing contaminant metals and chloride (see Table 4). From this last run, the recovered water and EG were combined to obtain approximately a 50/50 mixture for reinhibition with FTI inhibitor packages.

Two FTI reinhibitor packages were tested with the recombined water and EG solution (i.e., FTI#1 and FTI#2). The first package produced a clear, yellow-green antifreeze, which slowly formed significant amounts of a white, flocculent precipitate. In addition, the RA and pH values were much lower than expected for a fully formulated antifreeze, both new or recycled (see Table 2). The precipitate warranted nonacceptance of the FTI#1 system for use with the military antifreeze MIL-A-46153. Results of a glassware corrosion test confirmed this nonacceptance. As shown in Table 3, the FTI#1 package failed the corrosion test, exceeding the ASTM limits for the iron coupon.

After these observations for the FTI#1 package were made, FTI was notified of the results. A second FTI package (FTI#2) from another antifreeze inhibitor manufacturer was immediately offered for testing. The FTI#2 package produced a green, very turbid recycled antifreeze, having low RA and pH values, and a greater amount of a white, flocculent precipitate similar to the FTI#1 precipitate (see Table 2). This sample also failed glassware corrosion (see Table 3). Both FTI samples were thoroughly examined by the Center and FTI. From these examinations it was concluded that the observed precipitate formations were due to the residual borax in

the used "reference" MIL-A-46153 reacting with the FTI inhibitor packages. FTI officials examined the problem further and deduced that the borax upon heating forms a borax-ethylene glycol condensate with a low volatility. This volatility is low enough to allow the condensate to come over with the recovered EG. Once water is added, the borax is released thereby acting as a strong acidic buffer which detrimentally affects the reinhibition of the solution. The resultant solution is characterized by low pH and RA values and the presence of a precipitate. Once the apparent inhibitor problems of the FTI samples were observed, testing was limited to those shown in Table 2, Table 3, and Table 4. Because of the aforementioned problems, nonacceptance of the FTI system will remain in effect until the system is modified to obtain compatibility with used MIL-A-46153.

THE FPPF CHEMICAL COMPANY (FPPF) SYSTEM

A schematic of the Glyclean unit examined is shown in Figure 3. The system processes 25 to 100 gallons of used antifreeze per batch at a rate of 150 gallons/hour. The system incorporates filtration and chemical pretreatment to remove insoluble and soluble contaminants from the used antifreeze. The used antifreeze can be poured directly into the unit's 100-gallon holding tank or transferred from a drum or other container using the system pump and hose assembly. Once in the tank, the antifreeze is recirculated through two filters, 5 and 20 micron porosity, until all insoluble contaminants are removed. The pH and freeze point are measured and a proprietary additive package, the Glyclean Extender Additive, is added. The amount of additive added is determined by the initial pH level. The Glyclean additive package acts as an inhibitor package, a sequestering agent, and a precipitating agent. After the additive is added, it begins to precipitate and sequester dissolved contaminants such as metals and organic acids accumulated in the used antifreeze during normal operation. The recycling process is complete once the solution appears clean and has a pH 9.5 and 10.0. Water or new antifreeze concentrate are then added to obtain the desired freeze protection.

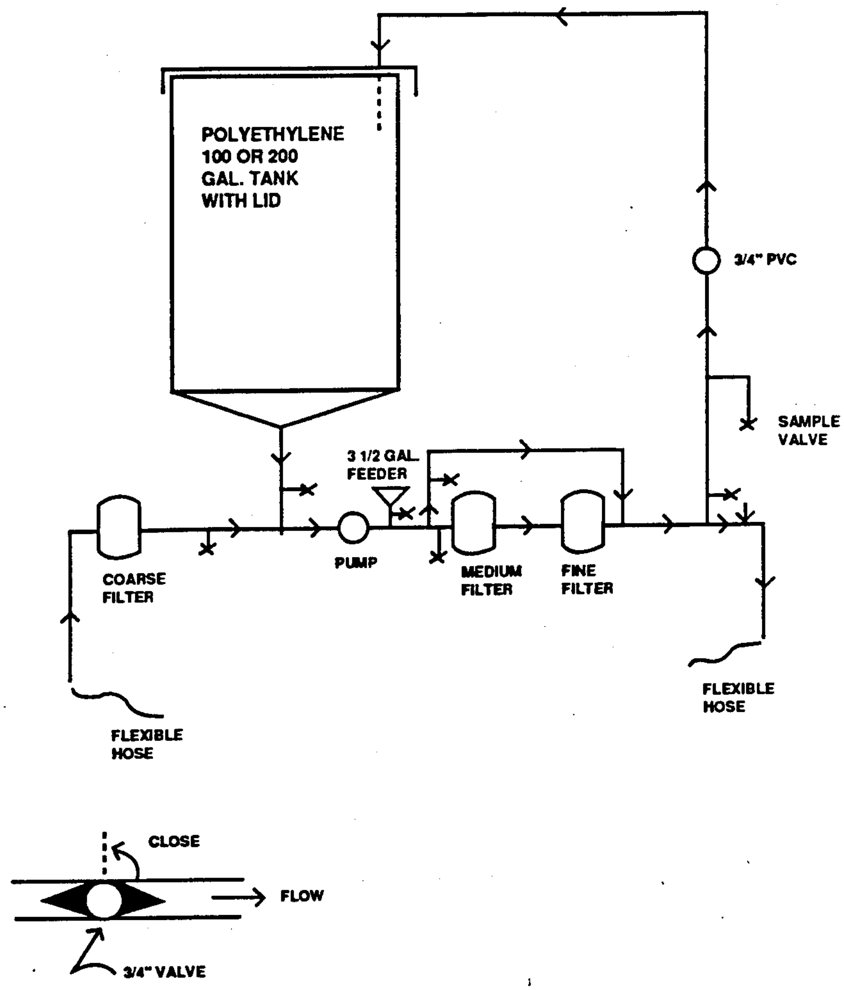


Figure 3. Glyclean Unit

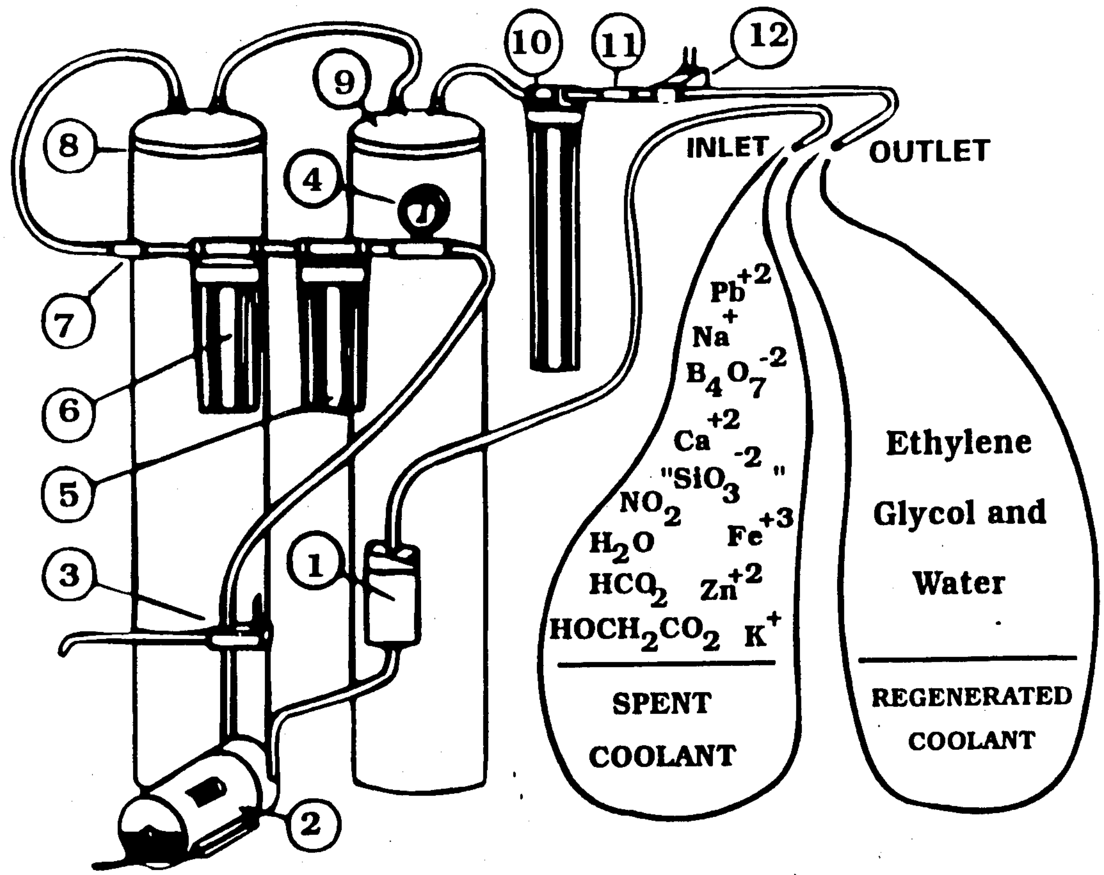
Thirty gallons of the "reference" used antifreeze were recycled by the Glyclean system. After adding the prescribed amount of Glyclean additive, the antifreeze was recirculated for approximately 20 minutes. The resultant solution was blue-green in color and very turbid in appearance. The system removed most of the contaminant metals, but essentially none of the contaminant chloride (see Table 4). In addition, moderate amounts of a fine yellow-white precipitate were observed on the bottom of the sample vessel. A FPPF representative suggested the solution be recirculated using 1 and 5 micron filters to remove the precipitate. Approximately 75% of precipitate was removed. The remaining precipitate was not removed even after 20 minutes of recirculation. The filters were changed once during the recirculation with no noticeable effect. Along with the turbidity and the precipitate, the pH was well below the 9.5 minimum stated in the instructions (see Table 3).

The low pH was attributed to the buffering action of the residual inhibitors still active in the used MIL-A-46153. This effect has been documented in a previous BRDEC study[9] of the Glyclean system and MIL-A-46153 antifreeze. The apparent incompatibility of the Glyclean additive with used MIL-A-4653 (i.e., low pH) and the presence of the precipitate warranted nonacceptance of the FPPF system for military use. However, to verify the possible damaging effects of this recycled antifreeze in a cooling system, performance tests were conducted. As shown in Table 3 and Table 5, the FPPF recycled sample passed the glassware test and water pump cavitation-erosion test, but failed the simulated service test by exceeding the ASTM limits for the copper and brass coupons. As shown in Table 5, a sample of equal parts FPPF recycled antifreeze and new MIL-A-46153 gave similar results showing incompatibility between the recycled antifreeze and MIL-A-46153. Because of these results and aforementioned pH and precipitate problem, nonacceptance of the FPPF system will remain in effect until the system is modified to obtain compatibility with used MIL-A-46153.

THE BG PRODUCTS INC. (BG) SYSTEM

A schematic of the BG unit examined is shown in Figure 4. The unit can be employed for individual vehicle recycling or batch recycling at rate 180 gallons/hour. The system employs three (3) filters and two (2) ion exchange tanks to remove insoluble and soluble contaminants. The filters remove the insoluble contaminants. The ion exchange tanks remove the soluble, ionic contaminants (i.e., possessing either a positive or negative electric charge). For instance, most dissolved contaminants found in used antifreeze are salts which possess electrical charges. These charged species are retained on chemically active resins inside the tanks. The system returns a clear mixture of deionized water and EG in the same ratio as the original used antifreeze. The freeze protection is adjusted using water or pure, uninhibited EG (i.e., contains no additives) concentrate depending on the protection desired. This mixture is reinhibited with a BG proprietary inhibitor package and ready for use.

Employing the batch mode of operation, a fifty-five gallon drum of the "reference" used antifreeze was recycled using the BG unit. The operation took approximately thirty minutes. The system was very effective in removing insoluble contaminants.



KEY	ITEM
1	Basket strainer intended to remove particulates/solid contaminates greater than one 15 micron size
2	Processing pump capable of processing 2-5 gallons minute
3	Switch-operated bypass valve
4	Pressure gauge intended as a maintenance monitoring device for overall system pressure. Pressure readings greater than 55 p.s.i. indicates filters have reached their capacity or flow has become restricted. Pressure readings less than 30 p.s.i. indicates leaks, loss of prime due to air pockets, low ion-exchange resin content, or misalignment of cotton filters.
5	First cotton-wound cartridge filter of 15 micron size which removes most of suspended solids
6	Second cotton-wound cartridge filter of 1.0 micron size. (Note: both cotton-wound cartridge filters contain activated carbon cores designed to remove organic contaminants)
7	One-way check valve to prevent back flush of any coolant through filters
8	First ion-exchange tank which removes all cations or positively-charged ions (e.g., sodium, calcium, etc.)
9	Second ion-exchange tank which removes all anions or negatively-charged ions (e.g., chloride, sulfate, formate, silicate, etc.)
10	Activated charcoal filter which removes gases entrained in the liquid or combustion by-products
11	One-way check valve to prevent back flush of any deionized liquid
12	Maintenance condictivity indicator which shows the condition of the ion-exchange resins. A red light indicates the conductivity of the deionized liquid ha exceeded 50 microsiemens/cm which signals replacement of the resin filters. A green light indicates the conductivity of the deionized liquid is below 50 microsiemens/cm or satisfactory operation.

Figure 4. BG Unit

The resultant solution was clear with no visible contaminants observed. The BG system also satisfactorily removed the soluble metal contaminants as shown in Table 4. The freeze protection of this solution was then adjusted using pure, uninhibited EG as prescribed in the operating instructions. To prevent ruining of this uninhibited 55-gallon solution through a mixing error, five gallon batches were removed and reinhibited individually as needed for tests. The reinhibited solutions were light green and translucent in appearance. No precipitate or rotten egg odor was observed. The pH and RA were 8.5 and 6.2mL respectively as shown in Table 2. The RA was within the normal range of 5mL to 7mL according to a BG representative, but the pH was not within the expected range of 9 to 11. This observation was attributed to residual borax buffer which has affected all the systems in this study. The lower than expected pH did not deleteriously affect the results of any of the performance tests shown in Table 3 and Table 5. As shown in Table 5, a sample of the BG recycled antifreeze and new MIL-A-46153 gave similar results thus indicating total compatibility with MIL-A-46153. The BG system was viewed as acceptable for military use.

Table 2. Used and Recycled Sample Characteristics

Sample	pH	RA	Freeze Point	Conductivity	Ash	Foam
Ref. Used	7.2	7.4mL	-25°F	2060µS/cm	0.69%	47mL/1.7s
FTI#1	7.2	3.3mL	-33°F	2024µS/cm	0.47%	97mL/4.5s
FTI#2	6.3	4.0mL	-38°F	2152µS/cm	0.81%	nt[1]
BG	8.5	6.2mL	-30°F	3652µS/cm	0.89%	63mL/3.7s
FPPF	7.7	11.5mL	-22°F	4394µS/cm	1.03%	53mL/1.7s
KFC	7.2	7.4mL	-25°F	2030µS/cm	nt	nt
New MIL 50-50	7.6	13.0mL	-34°F	2876µS/cm	0.64%	42mL/1.4s

[1] *"nt" - not tested*

Table 3. Glassware Corrosion Test Results

Weight Change, mg/Specimen

Sample	Copper	Solder	Brass	Steel	Iron	Aluminum
Ref. Used	10	1	5	5	156	4
FTI#1	1	18	3	2	15	+5[1]
FTI#2	11	4	19	6	15	+7
BG	1	3	4	0	3	0
FPPF	0	7	3	1	0	4
New MIL	1	7	3	2	1	+1
ASTM max Limits[2]	10	30	10	10	10	30

[1]*A plus (+) value represents a weight gain.*

[2]*Recommended weight loss maximums for ASTM standards for light-duty (D-3306), heavy-duty (D-4985), and prediluted, light-duty (D-4656) antifreezes.*

Table 4. Soluble Contaminants Concentration

mg/L (ppm)

Sample:	Ref. Used	KFC	BG	FPPF	FTI#1	FTI#2
Lead	4	2	<1	2	nd[1]	3
Iron	35	nd	1	15	4	4
Copper	<1	<1	<1	<1	1	<1
Aluminum	nd	nd	nd	nd	nd	nd
Chloride	25	nt[2]	10	24	nt	nt

[1]*"nd" - not detected*
[2]*"nt" - not tested*

Table 5. Simulated Service and Water Pump Cavitation-Erosion Test Results

Simulated Service: weight change, mg/specimen	Ref. Used	BG	FPPF	ASTM Limits[1]	New MIL
Copper	23	10(4)[2]	24(22)	20	10
Solder	49	1(7)	2(4)	60	4
Brass	26	14(9)	24(25)	20	10
Steel	96	0(0)	2(4)	20	4
Cast Iron	5	0(2)	7(5)	20	1
Cast Aluminum	130	1(2)	2(6)	60	35
Cavitation-Erosion:					
Rating	9	8(8)	8(9)	8 min	7

[1] *Recommended weight loss maximums for ASTM standards for light-duty (D-3306), heavy-duty (D-4985), and prediluted, light-duty (D-4656) antifreezes.*

[2] *The number in parenthesis is the value for a sample of one (1) part recycled antifreeze and one (1) part new MIL-A-46153 mixed with the appropriate amount of ASTM corrosive water to satisfy test sampling requirements.*

Section IV
Discussion

From this study's results, it has been determined that recycling used MIL-A-46153 is physically possible. The study's emphasis on used MIL-A-46153 and its compatibility with individual systems was fully justified. MIL-A-46153 large buffering capacity affected all of the recycling systems in the study, including the one system found acceptable, the BG Products Inc system. The BG system was most effective because it was able to remove most of the residual borax additive present in MIL-A-46153, as well as the contaminants commonly found in used antifreeze.

From the results of this study a field guide for recycling used MIL-A-46153 was developed and issued to the field[10,11,12] prior to the release of this report. The guide provides recommendations to military and civilian personnel on the appropriate procedures to be followed for recycling used MIL-A-46153. A copy of the guide is included in Appendix 1. The guide does not give recommendations for recycling antifreeze from administrative vehicles or light-duty vehicles (i.e., cars, small trucks, etc.), which use commercial, automotive antifreeze. Maintenance of these vehicles are increasingly being contracted to outside automotive service vendors. As such, policies concerning the recycling of used of antifreeze from these vehicles will have to be established by the vendors. For organizations that perform their own maintenance on light-duty vehicles it is suggested that the vehicle manufacturer be contacted for recommendations on the use of antifreeze recycling systems with their vehicles. For example, General Motors performed a study[13] that offers guidance on the use of recycling systems with GM vehicles.

The field guide currently has only the BG system listed as an accepted system. Evaluation of the BG system's cost of operation, ease of use, and other matters concerning it's peculiarities will be accomplished during the field use. During the interim, Kleer-Flo, Finish-Thompson, and FPPF Chemical are all working with the Center to develop compatible systems and eventual acceptance. Once compatibility with MIL-A-46153 has been established, these systems will also be listed in the field guide. In addition, the manufacturers whose systems were not included in this study will be allowed an opportunity to gain military acceptance. A testing protocol was developed and released shortly after the distribution of the aforementioned guide. The protocol gives complete instructions concerning how to test a system with MIL-A-46153. It is expected that several manufacturers will respond to the protocol so that more than one system will become available for military use.

References

1 Allan, Gordan G., "Report on Antifreeze Compound for Military Vehicles", Office of the Chief of Ordnance, Washington, D.C., F & L Report #12A-1, July 1944.

2 Conley, James H. and Jamison, Robert G., "Reclaiming Used Antifreeze", U.S. Army Mobility Equipment, Research, and Development Command, Fort Belvoir, VA, Technical Report #2168, March 1976.

3 MIL-A-53009, Additive, Antifreeze Extender, Liquid Cooling Systems, July 1991.

4 Davis, Dwayne, "An Evaluation of Three Commercial Processes for Recycling Used Military Antifreeze MIL-A-46153", U.S. Army Belvoir Research, Development, and Engineering Center, Fort Belvoir, VA, Technical Report #2520, June 1992.

5 MIL-A-46153, Antifreeze, Ethylene Glycol, Inhibited, Heavy Duty, Single Package, August 1991.

6 Hercamp, Richard D., "Recycling Coolants from Heavy-Duty Engines", SAE paper #921633, September 1992.

7 Conley, James H. and Jamison, Robert G., "Reclaiming Used Antifreeze", U.S. Army Mobility Equipment, Research, and Development Command, Fort Belvoir, VA, Technical Report #2168, March 1976.

8 Hudgens, Douglas R. and Bugelski, W.G., "Analysis of Coolants from Diesel Engines", Worldwide Trends in Engine Coolants, Cooling System Materials and Testing, SAE SP-811, Society of Engineers, Warrendale, PA, 1990, pp. 79-99.

9 U.S. Belvoir Research, Development, and Engineering Center, "Evaluation of Octagon Antifreeze Cleanup Using a Glyclean Antifreeze Recycler", Dwayne Davis, Letter Report #90-4, May 1990.

10 Memorandum SATBE-FL, dated 4 June 1993, subject: User Guide For Recycling Military Antifreeze.

11 "Users Guide For Recycling Military Antifreeze", U.S. Army Belvoir Research, Development, and Engineering Center, Fort Belvoir, VA, May 1993.

12 "Users Guide For Recycling Military Antifreeze", Fuels and Lubricants Quarterly Bulletin, U.S. Army Belvoir Research, Development, and Engineering Center, Fort Belvoir, VA, June 1993, vol 15-No.3, pp. 15-16.

13 Bradley, Wayne H., "An Evaluation of Engine Coolant Recycling Technology", SAE paper #921634, September 1992.

Appendix

ANTIFREEZE
USERS GUIDE
RECYCLING

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- CONTENTS -

USERS GUIDE FOR RECYCLING MILITARY ANTIFREEZE

1. **Purpose.** This Users Guide provides recommendations to military/civilian personnel on the appropriate procedures to be followed for recycling used military antifreeze which initially was procured under Military Specification MIL-A-46153. The guidance within this User Guide is to be used in conjunction with those detailed instructions provided by the manufacturer of the commercial recycling unit. The recycling unit is identified under paragraph 3.A of this User Guide.

2. **Background.** The three main reasons for recycling used antifreeze are to conserve our natural resources, reduce the cost of new antifreeze purchases, and reduce both the cost and problems associated with used antifreeze disposal. The latter reason is becoming a stronger impetus for recycling due to the increasing trend of federal, state and local governing agencies enacting stricter legislation on environmental protection matters. In some states, these more limiting regulations include identifying ethylene glycol (EG), the base material for most of today's antifreezes, as a hazardous material. Such a designation substantially raises the handling and storage expenses of new as well as used antifreeze.

Because of its less restricting chemistry when compared to automotive oils and fluids (e.g., transmission fluids, engine oil, etc), antifreeze is easier to recycle. This however does not eliminate the requirement for a recycling method that effectively reclaims the EG by complete removal of all contaminants, oxidation products, and depleted/residual inhibitors that typically form during the service life of antifreeze. New antifreeze is a precise balance of water and EG, which provides both low and high temperature protection, and is treated with chemical inhibitors that provide both corrosion protection to the engine's cooling system and protection against foaming. This balance is changed during normal use and therefore must be carefully reestablished for a recycled antifreeze to be reliable and effective as new antifreeze.

The U.S. Army Belvoir Research, Development, and Engineering Center's (BRDEC) recently completed a detailed investigation and evaluation in which four methods of recycling which are being commercially marketed were thoroughly examined. The methods examined involved vacuum distillation, chemical pre-treatment/ filtration, ultra-filtration, and ion exchange technologies. Each commercial system employs a reinhibition step following the recycling phase using a proprietary inhibitor package system which reportedly brings the recycled EG and water mixture to an acceptable quality of antifreeze. There are other commercially available methods of recycling being marketed which employ but are not limited to centrifuge/filtration and reverse osmosis

techniques. These methods along with any other technologies not included in this evaluation may be considered in the future. The detailed investigation and evaluation that was conducted focused primarily on (1) assessing the degree of contaminant removal and, (2) determining the compatibility of each system's inhibitor package system with the recycled EG and water mixture. This recycling program provided the necessary knowledge as to the preferred method to recycle used military antifreeze, MIL-A-46153 (Antifreeze, Ethylene Glycol, Inhibited, Heavy Duty, Single Package) which is the required antifreeze for all DOD ground vehicles and equipment.

The results generated from this investigation and evaluation revealed the most effective recycling methods for used MIL-A-46153 are those which consistently remove essentially all contaminants including dirt, metals, oxidation products, and depleted corrosion inhibitors. Complete removal of contaminants and inhibitors provides a clean starting material to which a balanced inhibitor package can be added without chemical interferences. The importance of removing depleted and/or residual inhibitors was made evident by incompatibilities observed when treating the recycled antifreeze generated from three of four systems evaluated in this program. These incompatibilities included precipitate formations, low pH, low buffering capacities (i.e., low reserve alkalinities), and turbid solutions, all of which or individually will cause increased maintenance to engine cooling systems or possibly premature failure of components such as water pumps, heater cores, etc due to inadequate corrosion protection and blockage of critical passage ways.

A brief summary of the four commercial recycling units that have been evaluated is provided on Attachment A. This chart, entitled "Summary on Commercial Antifreeze Recycler Evaluations for DOD Application", identifies the salient characteristics of each unit evaluated and a brief summary as to the quality of reclamation and additive compatibility that was found during this investigation. A final report on this program is in process and will be available shortly.

The recommendations contained within paragraphs 3 and 4 of this guide are intended for use by military organizations operating combat/tactical and administrative vehicles and equipment. Where the information in this User Guide is in conflict with other published data, the recommendations and guidance provided by this publication should prevail. For vehicles and equipment that may be under warranty, the manufacturer's instructions relative to use or non-use of recycled antifreeze should take precedent during the engine's warranty period.

2

3. **Recommendations for Recycling Used MIL-A-46153 Antifreeze.**

A. Recycling Unit

The Cool'r Clean'r Recycling System manufactured by BG Products Inc. has been evaluated and found to perform satisfactorily for reclaiming military antifreeze for combat/tactical vehicles, combat service support equipment, construction/material handling equipment, and mobile power generation equipment. A diagram of this system is provided on Attachment B. Details on the Cool'r Clean'r system are as follows:

Manufacturer - BG Products Inc, PO Box 1282, Wichita, Kansas 67201. POC: Mr. Harold Erwin, (316) 265-2686

Model - Cool'r Clean'r Recycling System

Process - Ion Exchange

Process Rate - 180 gal/hour

Power Requirements - 110 Volts - 10 amps (Not UL Approved)

Operators Required - One (1)

Inhibitor Required - BG 570A/B (Heavy Duty), Dearborn Chemical

Hazardous Waste - Generated Spent filters

Approximate Equipment Cost - $8,750

Total Operating Cost/gal - $4.06[1]

The "Cool'r Clean'r Coolant Purification System" Operator's Manual is available and provided with each unit. Individuals desiring a copy of this manual should contact the BG Products Inc Point of contact identified above.

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[1]Value taken from General Motors Engine Coolant Recycling Equipment Overview as provided by BG Products Inc and is based on a 5-year depreciation rate of @ 2000 gal/yr, not including interest on equipment. If your organization generates significantly less than 2000 gallons of used antifreeze per year, the cost/gal will increase as a result equipment amortization.

B. Used Antifreeze Feedstock

Do not contaminant used antifreeze intended for recycling with engine oil, brake fluid, transmission fluid, hydraulic fluid, gear oil, solvent, gasoline, diesel fuel, aviation turbine fuel, heating oil, kerosene, preservative, and used arctic-type antifreeze (MIL-A-11755) by collecting the used antifreeze in a labeled, dedicated 55-gallon drum. Petroleum based fuels, fluids/oils, brake fluids, etc will clog the recycling system if admixed with used antifreeze. Used arctic antifreeze (MIL-A-11755) can be distinguished from other used antifreezes by its fluorescent orange color. Do not attempt to recycle used MIL-A-11755 as this product is a packaged ready-to-use antifreeze that does not require dilution. Because of fixed ratio of ethylene glycol and water required for MIL-A-11755, its recycling is not recommended at this time.

C. Operating Procedures

(1) The BG unit instructions are for single vehicle recycling. For example, the unit is attached directly to the vehicle's cooling system. However, the unit can be used for batch processing by recycling the used antifreeze using 55-gallon drums as holding containers. For simplicity and logistical reasons, it is recommended that antifreeze be recycled directly from drums and not from individual vehicles.

(2) Recycling used antifreeze from drums:

(a) Place inlet hose into drum containing used antifreeze.

(b) Place outlet hose into clean drum.

Warning: It is important that a clean plastic or plastic lined metal drum is used to avoid contaminating the recycled antifreeze. (Note: introducing the recycled antifreeze into non plastic lined drums increases the potential for one of the inhibitors used in MIL-A-46153 to chemically react with the internal drum surface which generates a black slime. This potential for reaction increases as the water content of the antifreeze-water mixture decreases).

(c) If a clean drum cannot be obtained, thoroughly clean a drum that previously contained new antifreeze by rinsing the drum with water and allowing it to drain and air dry. However, the recycled antifreeze should not be allowed to

remain in non-plastic lined drums for long periods of time.

(3) Use of the BG unit:

(a) Prime the unit using five (5) to seven (7) gallons of used antifreeze.

(b) Turn unit on and allow antifreeze from the outlet hose to flow back into the drum containing the used antifreeze.

(c) Check antifreeze for cleanliness. Fluid from the outlet hose should be as clear as clean water.

(d) When the fluid is clean, stop unit and place outlet hose in <u>clean drum</u> and continue recycling.

(e) Continue to check the cleanliness (i.e., clarity) of the recycled antifreeze from the outlet hose. If it starts to become turbid, murky or oily in appearance, immediately stop the unit and examine both filters.

(4) After recycling is complete:

(a) Add the two part heavy-duty inhibitor package (BG 570A/B) according to manufacturer instructions.

(b) Mix thoroughly by stirring or use some other means of agitation to completely disperse the inhibitor package.

(c) Check the Reserve Alkalinity (RA) with an Antifreeze Freeze Point and Corrosion Test Kit (NSN 6630-01-011-5039) to insure the antifreeze has been prepared correctly.

(d) A properly processed antifreeze will be identified by a <u>RA pad color of light green</u> (6 RA units) to <u>blue</u> (10 RA units) as shown on the color chart of the test kit. A recycled antifreeze having a color lighter than that indicated (i.e., less than 6 RA units) should be recycled again, starting with the procedure in paragraph C.3 above.

(5) After the proper RA has been verified:

(a) Check the freeze point protection of the reclaimed antifreeze water mixture with an Antifreeze Coolant and Battery Tester (NSN 6630-150-1418) or the Antifreeze Freeze Point and Corrosion Test Kit.

(b) A freeze point of -34°F (-37°C) or 50/50 solution (reprocessed antifreeze/water) is suitable for all warm weather and most cold weather climates.

(c) If needed, adjust the freeze point to -34°F (-37°C) or lower with the addition of new MIL-A-46153 antifreeze concentrate.

(6) The recycled antifreeze is now ready for use.

D. Recommendations and Precautions

(1) Use of recycled antifreeze should be limited to one (1) year (e.g., after 12,000 miles or 350 hours of use). After one year, the antifreeze can again be recycled following the procedures outlined in paragraph 3C. (Note: this one year limit was based upon commercial practice. Controlled field testing would be required to determine whether this could be extended).

(2) Do not use the Antifreeze Extender Additive (MIL-A-53009) with the recycled antifreeze. MIL-A-53009 was designed to extend the service life of MIL-A-46153 and is not designed to be used with recycled antifreeze. Use of MIL-A-53009 with recycled antifreeze may result in the compatibility problems described in paragraph 2.

(3) With the one year limitation identified in paragraph 3.D.(1), it is recommended that some means of identification be provided to set these vehicles apart from those which are using non-recycled MIL-A-46153. Technical Bulletin TB 750-651 on use of MIL-A-46153 specifies use of the DD Form 314 (Preventative Maintenance Schedule and Record). This should be used to record the type of antifreeze in use.

(4) The BG recycled antifreeze can be used with new MIL-A-46153 antifreeze without any ill effects.

(5) This Guide recommends use of the BG Products Inc. unit for recycling used MIL-A-46153. Use of the unit with any other antifreezes that have not been evaluated will be the sole responsibility of the user. This includes commercial antifreezes (e.g., Prestone, Zerex, Peak, etc) and other specification products (e.g., Commercial Item Description A-A-870 and MIL-A-11755).

(6) As this Guide recommends the BG Products Inc. unit for recycling used MIL-A-46153, use of any other recycling method is not recommended.

E. Disclaimer

The recommendation given in the above paragraph 3.D relative to use of the BG Products Inc "Cool'r Clean'r Recycling System" is not meant as an endorsement as such, but merely to identify a commercially-marketed recycling system using ion-exchange technology and its supplemental inhibitor package that collectively was found to produce a satisfactory quality of recycled military antifreeze. The other recycling systems that were concurrently evaluated were unable to generate a satisfactory quality of recycled military antifreeze; however, this does not mean that these other systems are unsatisfactory for use with commercially-marketed antifreeze mixtures. The testing and evaluation that was conducted was targeted solely for recycling military antifreeze (MIL-A-46153) which is based upon a single formulation and not for recycling commercial antifreeze. Should there be other recycling technologies or new systems that become commercially available, the manufacturers will be given an opportunity to demonstrate their systems capabilities in recycling military antifreeze. If it can be demonstrated that new systems effectively reclaim and are compatible with military antifreeze, this Guide will be revised to include those additonal units.

4. **Points-of-Contact**. Should questions arise relative to this User Guide and its contents, the following individual should be contacted:

Mr. Dwayne Davis
DSN 654-3720
Commercial (703) 704-3720

In the absence of Mr. Davis, the following alternate individual is given:

Mr. Al Rasberry
DSN 654-3733
Commercial (703) 704-3733

Any comments, recommendations, etc to improve the overall utility of this User Guide should be sent to the following address:

CDR
US Army Belvoir Research Development & Engineering Center
ATTN: SATBE-FLH
Ft. Belvoir, VA 22060-5606
Facsimile Number - (703) 704-1822

5. **References.** The following references were used to write this guide and should be consulted for additional information concerning recycling used antifreeze:

a. U.S. Army Mobility Equipment Research and Development Command, MERADCOM Report #2168, "Reclaiming Used Antifreeze", by James H. Conley and Robert G. Jamison, March 1976.

b. U.S. Army Mobility Equipment Research and Development Command, MERADCOM Report #2265, "Development of An Antifreeze Extender and Water Inhibitor for Automotive Cooling Systems", by James H. Conley and Robert G. Jamison, December 1978.

c. Society of Automotive Engineers, SAE Paper #790415, "Research and Development Efforts in Military Antifreeze Formulations", by James H. Conley and Robert G. Jamison, February 1979.

d. Society of Automotive Engineers, SAE Paper #881270, "Filtration of Coolants for Heavy Duty Engines", by R. D. Hudgens and Richard D. Hercamp, September 1988.

e. U.S. Army Belvoir Research, Development, and Engineering Center, BRDEC Letter Report #90-4, "Evaluation of Octagon Antifreeze Clean-Up Using a Glyclean Antifreeze Recycler" by Dwayne Davis, May 1989.

f. U.S. Environmental Protection Agency, Office of Research and Development, "Automotive and Heavy-Duty Engine Coolant Recycling by Filtration" by Arun R. Gavaskar, Robert F. Olfenbuttel, Jody A. Jones, and Paul R. Webb, Battelle, October 1991.

g. U.S. Environmental Protection Agency, Office of Research and Development, "Automotive and Heavy-Duty Engine Coolant Recycling by Distillation" by Arun R. Gavaskar, Robert F. Olfenbuttel, and Jody A. Jones, Battelle, October 1991.

h. U.S. Army Belvoir Research, Development, and Engineering Center, BRDEC Report #2520, "An Evaluation of Three Commercial Processes for Recycling Used Military Antifreeze MIL-A-46153", by Dwayne Davis, June 1992.

i. Society of Automotive Engineers, SAE Paper #921633, "Recycling Coolants From Heavy-Duty Engines", by Richard D. Hercamp, September 1992.

j. Society of Automotive Engineers, SAE Paper #921634, "An Evaluation of Engine Coolant Recycling Technology", by Wayne H. Bradley, September 1992.

k. Society of Automotive Engineers, SAE Paper #921636, "Heavy-Duty Coolant Regeneration by Dual-Resin Deionization", by Rene D. Wiebe and John M. Dick, September 1992.

l. General Motors Service Technology Group, Taken from a presentation given by Wayne H. Bradley and Dale Jurette, November 1992.

m. Military Specification MIL-A-11755 Antifreeze, Arctic-Type Antifreeze.

n. Military Specification MIL-A-46153 Antifreeze, Ethylene Glycol, Inhibited, Heavy Duty, Single Package.

o. Military Specification MIL-A-53009 Additive, Antifreeze Extender Liquid Cooling Systems.

p. Commercial Item Description A-A-51461 Test Kit, Antifreeze Freeze Point and Corrosion.

q. Commercial Item Description A-A-870 Antifreeze/Coolant, Engine: Ethylene Glycol, Inhibited Concentrated.

r. Department of the Army Technical Bulletin TB 750-651, "Use of Antifreeze Solutions, Antifreeze Extender, Cleaning Compounds, and Test Kits in Engine Cooling Systems", 12 February 1989.

s. "Cool'r Clean'r Coolant Purification System" Operators Manual, BG Products Inc, 1993.

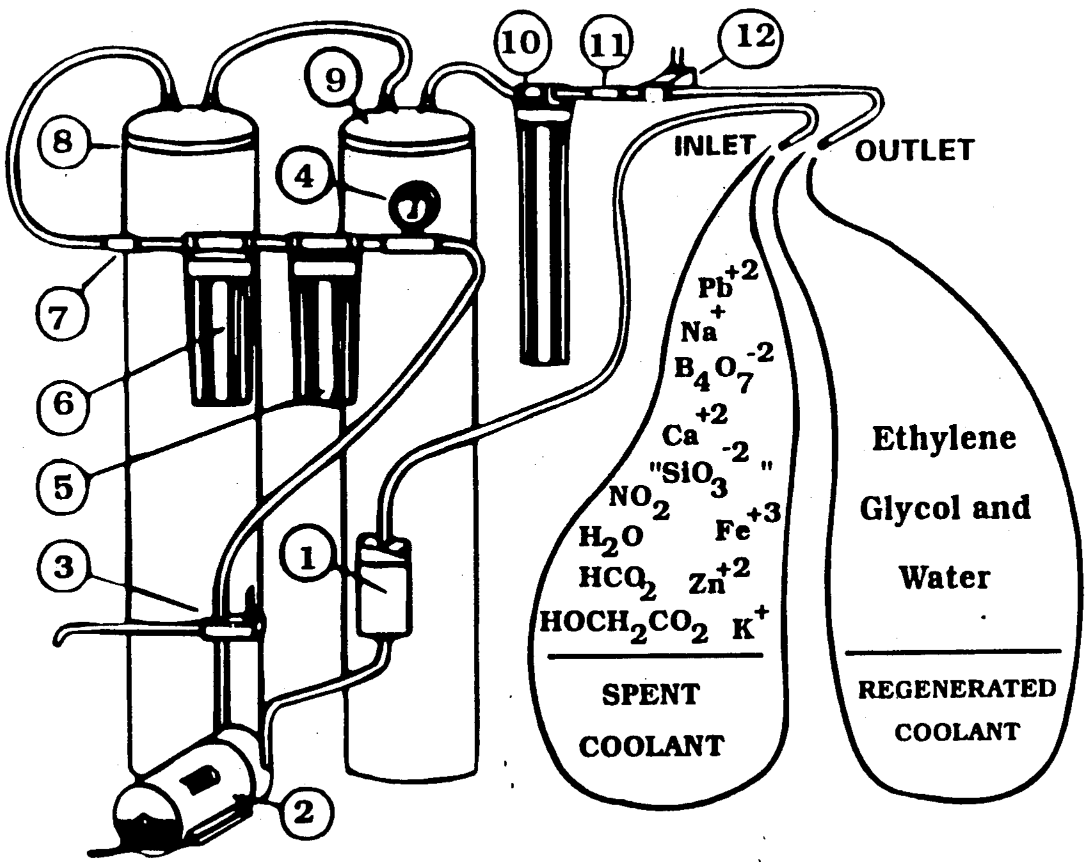
SUMMARY ON COMMERCIAL ANTIFREEZE RECYCLER EVALUATIONS FOR DOD APPLICATION

PROCESS TYPE	Ion Exchange	Vacuum Distillation	Chemical Pretreatment and Filtration	Ultra-Filtration
PROCESS RATE (gal/hr)	180	1	150	6
FEEDSTOCK LIMITATIONS	Oil Contamination	Oil Contamination	Oil Contamination	Oil Contamination
REPLACEMENT FILTER(S) REQUIRED	Yes(1 & 5 micron filters)	None	Yes(1 & 5 micron filters)	Yes(.0025 & 5 micron filters)
FILTER REPLACEMENT INTERVAL	@ Every 200-250 gallons	NA	@ Every 100-300 gallons	@ Every 100 gallons
SUPPLEMENTAL ADDITIVES REQUIRED	Yes	Yes	Yes	Yes
EASE OF OPERATION	Most Difficult	Moderate Difficulty	Moderate Difficulty	Least Difficult
PERSONNEL REQUIRED	1	1	1	1
HAZARDOUS WASTE REMAINING	Spent Filters	NA	Spent filters	Spent filters
RECOMMENDED CHANGE INTERVAL FOR RECYCLED ANTIFREEZE	After one year's use	After one year's use	After one year's use	After ones year's use
RESULTS OF EVALUATION: Quality of Reclamation Compatible with MIL-A-46153[1] Compatible with MIL-A-53009[2]	 Satisfactory Yes Yes	 Unsatisfactory No No	 Marginal Yes No	 Unsatisfactory No No
RECOMMENDED FOR DOD USE	Yes	No	No	No

June 1993

[1]MIL-A-46153 - Antifreeze, Ethylene Glycol, Inhibited, Heavy Duty, Single Package

[2]MIL-A-53009 - Additive, Antifreeze Extender, Liquid Cooling Systems



KEY	ITEM
1	Basket strainer intended to remove particulates/solid contaminates greater than one 15 micron size
2	Processing pump capable of processing 2-5 gallons minute
3	Switch-operated bypass valve
4	Pressure gauge intended as a maintenance monitoring device for overall system pressure. Pressure readings greater than 55 p.s.i. indicates filters have reached their capacity or flow has become restricted. Pressure readings less than 30 p.s.i. indicates leaks, loss of prime due to air pockets, low ion-exchange resin content, or misalignment of cotton filters.
5	First cotton-wound cartridge filter of 15 micron size which removes most of suspended solids
6	Second cotton-wound cartridge filter of 1.0 micron size. (Note: both cotton-wound cartridge filters contain activated carbon cores designed to remove organic contaminants)
7	One-way check valve to prevent back flush of any coolant through filters
8	First ion-exchange tank which removes all cations or positively-charged ions (e.g., sodium, calcium, etc.)
9	Second ion-exchange tank which removes all anions or negatively-charged ions (e.g., chloride, sulfate, formate, silicate, etc.)
10	Activated charcoal filter which removes gases entrained in the liquid or combustion by-products
11	One-way check valve to prevent back flush of any deionized liquid
12	Maintenance condictivity indicator which shows the condition of the ion-exchange resins. A red light indicates the conductivity of the deionized liquid ha exceeded 50 microsiemens/cm which signals replacement of the resin filters. A green light indicates the conductivity of the deionized liquid is below 50 microsiemens/cm or satisfactory operation.

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1 VEHICLE PROPULSION DIR
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CDR AMSAA
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1 ATTN AMXSY L
APG MD 21005-5071

CDR ARMY AMCCOM
1 ATTN AMXEN U (BEDTRAM)
1 ATTN AMSNC MA
ROCK ISLAND IL 61299-6000

CDR APC
1 ATTN SATPC Q
1 ATTN SATPC QE (BLDG 85 3)
NEW CUMBERLAND PA 17070-5005

1 PETROL TEST FAC WEST
BLDG 247 TRACEY LOC
DDRW
P O BOX 96001
STOCKTON CA 95296-0960

CDR ARMY TECOM
1 ATTN AMSTE TA R
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1 ATTN AMSTE EQ
APG MD 21005-5006

PROJ MGR PETROL WATER LOG
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ST LOUIS MO 63120-1798

PROJ MGM MOBILE ELEC PWR
1 ATTN AMCPM MEP
1 7798 CISSNA RD STE 200
SPRINGFIELD VA 22150-3199

CDR FORSCOM
1 ATTN AFLG TRS
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CDR TRADOC
1 ATTN ATCD SL 5
INGALLS RD BLDG 163
FT MONROE VA 23651-5194

CDR ARMY ARMOR CTR
1 ATTN ATSB CD NL
1 ATTN ATSB TSM T
FT KNOX KY 40121-5000

CDR
ARMY COMBINED ARMS SPT CMD
1 ATTN ATCL MRO (D CUNNELS)
1 ATTN ATCL CD
1 ATTN ATCL MS
FT LEE VA 23801-6000

CDR ARMY FIELD ARTY SCH
1 ATTN ATZR LSM (R STRINGFELLOW)
1 ATZR E (SCOTT)
1 ATTN ATSF CD
FT SILL OK 73503

CDR ARMY INF SCHOOL
1 ATTN ATSH CD
1 ATTN ATSH AT
FT BENNING GA 31905-5000

CDR ARMY ENGR SCHOOL
1 ATTN ATSE CD
FT LEONARD WOOD MO 65473-5000

CDR ARMY ORDN CTR
1 ATTN ATSL CD CS
APG MD 21005

CDR ARMY CSTA
1 ATTN STECS EN
1 ATTN STECS LI
1 ATTN STECS AE
1 ATTN STECS AA
1 ATTN STECS EF (R GOVANI)
1 ATTN STEAP SH EE (H GALLIFORD)
1 ATTN STEAP SH EE (M WORSHAM)
APG MD 21005-5059

CDR ARMY YPG
1 ATTN STEYP HT TL N
YUMA AZ 85365-9130

CDR ARMY CERL
1 ATTN CECER EN
P O BOX 9005
CHAMPAIGN IL 61826-9005

CDR I CORPS AND FT LEWIS
1 ATTN AFZH CSS
1 ATTN AFZH DEQ (D POWERS)
1 ATTN AFZH DEQ (TROUT)
FT LEWIS WA 98433-5000

CDR
RED RIVER ARMY DEPOT
1 ATTN SDSRR QA TS (A HOEHN)
1 ATTN SDSRR M
1 ATTN SDSRR Q
TEXARKANA TX 75501-5000

CDR 6TH ID (L)
1 ATTN APUR LG N
1060 GAFFNEY RD
FT WAINWRIGHT AK 99703

DEPARTMENT OF THE NAVY

CDR
NAVAL SEA SYSTEMS CMD
1 ATTN SEA 03M3
2531 JEFFERSON DAVIS HWY
ARLINGTON VA 22242-5160

CDR
NAVAL SURFACE WARFARE CTR
1 ATTN CODE 63
1 ATTN CODE 632
1 ATTN CODE 859
3A LEGGETT CIRCLE
ANNAPOLIS MD 21401-5067

1 CDR
NAVAL PETROLEUM OFFICE
CAMERON STA T 40
5010 DUKE STREET
ALEXANDRIA VA 22304-6180

DEPARTMENT OF THE NAVY/US MARINE CORPS

HQ USMC
1 ATTN LPP
WASHINGTON DC 20380-0001

1 PROG MGR COMBAT SER SPT
MARINE CORPS SYS CMD
2033 BARNETT AVE STE 315
QUANTICO VA 22124-5080

1 PROG MGR GROUND WEAPONS
MARINE CORPS SYS CMD
2033 BARNETT AVE
QUANTICO VA 22134-5080

1 PROC MGR ENGR SYS
MARINE CORPS SYS CMD
2033 BARNETT AVE
QUANTICO VA 22134-5080

CDR
MARINE CORPS SYS CMD
1 ATTN SSE
2033 BARNETT AVE STE 315
QUANTICO VA 22134-5010

CDR
BLOUNT ISLAND CMD
1 ATTN CODE 922/1
5880 CHANNEL VIEW BLVD
JACKSONVILLE FL 32226-3404

CDR
MARINE CORPS LOGISTICS BA
1 ATTN CODE 837
814 RADFORD BLVD
ALBANY GA 31704-1128

CDR
2ND MARINE DIV
PSC BOX 20090
CAMP LEJEUNNE NC 28542-0090

1 CDR
1ST MARINE DIV
CAMP PENDLETON CA 92055-5702

DEPARTMENT OF AIR FORCE

HQ USAF/LGTV
1 ATTN VEH EQUIP/FACILITY
1030 AIR FORCE PENTAGON
WASHINGTON DC 20330-1030

1 AIR FORCE HEEP MGMT OFC
615 SHSQ/LGTY MEEP
201 BISCAYNE DR STE 2
ENGLIN AFB FL 32542-5303

1 5A ALC/SFT
1014 ANDREWS RD STE 1
KELLY AFB TX 78241-5603

1 WR ALC/LVRS
225 OCNULGEE CT
ROBINS AFB GA 31098-1647

DEPARTMENT OF DEFENSE

DIR DLA
1 ATTN DLA NNDI
1 ATTN DLA MNSB
CAMERON STA
ALEXANDRIA VA 22304-6100

CDR
DEFENSE GEN SUPPLY CTR
1 ATTN DGSC SSA
1 ATTN DGSC SSE (W SMITH)
1 ATTN DGSC STAC (C MYERS)
8000 JEFFERSON DAVIS HWY
RICHMOND VA 23297-5678

12 DEFENSE TECH INFO CTR
CAMERON STATION
ALEXANDRIA, VA 22314

1 MDW DESK LOG
BLDG 17 DR 10
ATTN L FIORENTINO
CAMERON STATION
ALEXANDRIA VA 22304-5050

1 62 TRNS LGTM
761 BATTERY RD BLDG 779
ATTN SGT TILLMAN
MCHORD AFB WA 98438-1127

1 US ARMY CORPS OF ENGRS
ATTN CAMM OP R
PO BOX 2288
MOBILE AL 36628-0001

1 EDGAR POE
NAVAL RES ENVRMT AFFR
BLDG 1059 MARINE CORP
TWENTY NINE PALMS CA 92278-5000

1 857TH CES DEVE
BLDG 445
MINOT AFB ND 58705-5000

1 MARINE CORP LGO BASE
NATL RES ENVRL OFFICE
ATTN AL HARGROVE
CODE 560
ALBANY GA 31704

1 DEH
ENVRL DIVISION
ATTN ATZR E SCOTT
FT SILL OK 73503-5100

1 MMC MSWSES
FRANCISCO TADAY
SAFETY CODE 0009
PORT HUENEME CA 93043

1 DEH
ATTN BRMD L CLEMONS
FT DRUM NY 13602-5097

1 HQ USAF CEV
BOLLING AFB
ATTN CPT J HROMOWYK
WASHINGTON DC 20332-5000

1 SAFETY LINE MAGAZINE
CODE 722 EDITOR
RAE MAGILL
NAVAL SAFETY CTR NAS
NORFOLK VA 23511

1 HQ MACK LEMSB
ATTN SGT SHAW
SCOTT AFB IL 62225-5001

1 US ARMY FT GREELEY
ATTN APVR FG DE ROSSI
SEATTLE WA 98733

1 NATNL GUARD INDIANA
2002 S HOLD RD
ATTN MD FE EN CPT ORE
INDIANAPOLIS IN 46241-0326

1 LETTERKENNY ARMY DEPOT
ENVRL MAN DIV BLDG 363
ATTN SDSLE EN UPSTAIN
CHAMBERSBURG PA 17201

1 SUPPLY & SERVICE DIV
ATTN ATZC ISL S
FT BLISS TX 79916

1 III CORP G4
ATTN AFTZ GL (CPT YOCKUM)
FT HOOD TX 76546

1 NWR DEPT
NAVAL AIR STATION
ATTN S KOWALSKI
FALLON NV 09406-5000

1 ADJT GENL IOWA
CAMP DODGE
ATTN AGIA FAC E (GAICH)
7700 BEAVER DR
JOHNSTOWN IA 50131

1 MAJ D CORNELL
ATTN OC LAC EMW
TINKER AFB OK 73145

1 CDR 10TH MOUNTAIN DIV
DEH ENVRL OFFICE
ATTN AFZX DH E
FT DRUM NY 13602-5000

1 JILL RUSH
436 CES DEEV
DOVER AFB DE 19902-5516

1 MIKE MARKER
2750TH ABW EMC
WRIGHT PATTERSON AFB OH 45433-5000

1 ARMY RES MAIT SUP SHOP
ATTN AMSA5 F ELLESER
2800 CRESTLINE RD
FT WORTH TX 76107

1 ERNEST EDDY
HHC 8TH USA ARMY
PSC303 PO BOX 78
APO AP 96205-0078

1 CDR HHB 1ST BATTLN
43RD ADA
ATTN BMO
FT BLISS TX 79916

1 CDR HHB 1ST BTTLN
62ND TRANS CO
FT BLISS TX 79916

1 CDR NEW CUMBERLAND ARMY
DEP DIR MAINT
ATTN SDSNC M
NEW CUMBERLAND PA 17070

1 MK1 BURNS
CGSTA BURLINGTON
DEPOT ST
BURLINGTON VT 05401

1 BILL CONN
HQ 18TH AIRBORN CORP
FT BRAGG DEH
ATTN AFZA DEDV
FT BRAGG NC 28307-5000

1 CHIEF NG BUREAU
ATTN NGB ARL SM (MADDEN)
ARLINGTON HALL STATION
BLDG T420
ARLINGTON VA 22304-1382

1 BRH MED CLINIC
INDRL HYGNT
MARINE CORP LOG BASE
BARSTOW CA 92311

1 MSG M KRIZ
5TH MAINT SQUAD
MINOT AFB ND 58704

1 LESTER DZIUK
ATTN SA LAC SFTT
KELLY AFB TX 78241-5000

1 DAVID DAVIS
US ARMY ENVL HYG AGY
WASTE DISPOSAL
APG MD 21010-5422

1 JOHM SHIMP
DEH BLDG 408
ENVRL & NATL RES DIV
FT RILEY KS 66442-6016

1 CDR ANNISTON ARMY DEPOT
DIR MAINT
ATTN SDSAN M
ANNISTON AL 36201-5000

1 MSG T SMITH
60TH MAW MASE
TREVIS AFB CA 94535

1 PEGGY HARLOWE
CONN NG
360 BROAD ST
HARTFORD CT 06805-3795

1 VINCENT TUNG
8403 LEE HWY
MERRIFIELD VA 22080-8101

1 LTC MARK HAGUE
COLORADO NATL GUARD
6848 REVERE PARKWAY
ENGLEWOOD CO 80112

1 WASHINGTON ST MIL DEPT
ATTN FMO ENGR
G MATTHEWS
BLDG 33 CAMP MURRAY
TACOMA WA 98430-5054

1 DAVE ELLOIT
SAN ANTONIO ALC
ATTN LDPT
KELLY AFB TX 78241

1 CDR LETTERKENNY ARMY DEP
ATTN SDSLE MME (K GULYAS)
BLDG 1C
CHAMBERSBURG PA 17201-4150

1 JIM PARKER
NC DEPT TRANS EQUIP UNIT
4809 BERYLE ST
RALEIGH NC 27600

1 KEN WALLER
AEROSPACE FUELS LAB
C BLDG 1
10 PARK AVE
MUKILTEO WA 78275

1 CDR TOOELE ARMY DEPOT
DIR MAINT
ATTN SDSTE M
TOOELE UT 84074-5011

1 CDR USCG GRP UPR MISS
221 MISSISSIPPI DR
ATTN CHIEF CANDLER
KEOKUK IA 52632

1 NICKS KNOPES
WR ALC LZEC
ROBBINS AFB GA 31098

1 CDR TOBYHANNA ARMY DEPOT
ATTN PAT TIERNEY
TOBYHANNA PA 18466-5075

1 NSS FACLTY
NEW LONDON CONN
NAVSEA OFF KING
PO BOX 300
GROTON CT 06349

1 AIR NATL GUARD
ATTN ANGRC LGMSE (VILLA)
3500 FETCHT AVE
ANDREWS AFB MD 20331-5151

1 CIVIL ENGR SUPP
ATTN S JOHNSON
CODE 15741
PORT HUENEME CA 93043-5000

1 ADJ GENRL PENN
US PRPTY OFF FIS PENN
ATTN CW2 R SCHAFFER
DEPY MILITARY AFFRS
ANNVILLE PA 17003-5002

1 HQ FT DEVENS
ATTN AFZD EM (C WILLIAMS)
PO BOX 19
FT DEVENS MA 01433

1 USALAL
ATTN AMXLA C E DV
K DESAUPELS
FT DEVENS MA 01433-5880

1 FACLTYS EN GRG
LTC HURELY
US CG TRNG CTR
CAPE MAY NJ 08204

1 WYOMING ARMY NG
SURFACE MAINT
PO BOX 1709
ATTN CPT SHEPPARD
CHEYENNE WY 02003-1709

1 US ARMY CORP ENGRS
LA CLAIR
BASE PLANT
ATTN OD MP J WILSON
PO BOX 2004
ROCK ISLAND IL 61204-2004

1 CORKY CROVATO
KASCO FUEL MAINT
4481 BEECH RD
TEMPLE HILLS MD 20748

1 FPPF CHEMICAL CO
ROBERT MILLER
32 MONROE AVE
ROSELAND NJ 07068

1 FINISH THOMPSON INC
PETER SCANTLEBURY
921 GREENGARDEN RD
ERIE PA 16501-4478

1 LTC CHARLES SMITH
HQ USMC
CODE LFS 2
WASHINGTON DC 20380

1 USA ARMY LOG ASS OFFC
ATTN AMXLA CE JK
AL NELSON
PO BOX 10010
FT JACKSON SC 29207-0010

1 TOOELE ARMY DEPOT
ATTN SDSTE PAQ (D COX)
TOOELE UT 84074

1 TOOELE ARMY DEPOT
BLDG 113
ATTN R RAFMUSSEN
TOOELE UT 84074

1 JENS KNUDSEN
ATTN GC LGTM
TOOLEY AFB GREENLAND
12 SWSAPO AE 09704-5000

1 RENE WIBE
CHEMIST
BG PRODUCTS INC
701 S WITCHITA ST
WICHITA KS 67213

1 RASCO
GERALD ESKELUND CEP
1635 3 WOODSIDE DR
WOODBRIDGE VA 22191

1 MARVIN LEATH ASS
ROBERT NOVOGRATZ
SUITE 300
ONE MASS AVE NW
WASHINGTON DC 20001

1 FIRST BRANDS CORP
COOLANT DEVE
PETER SOYCIESJES
55 FEDERAL RD
DANBURY CT 06810

1 GARY SNYDER
615 SMSQ LGTV MEEP
201 BISCAYNE RD SUITE 2
EGLIN AFB FL 32542-5303

1 DEF FUELS OFF ALASKA
6920 12TH ST
ATTN FUELS LAB (SOHLBURG)
ELMENDORF AFB ALASKA
99506-2570

1 AMC INSTLNS SER ACT
ATTN AMXEN U (BEDTRAM)
ROCK ISLAND IL 61299

1 CDR DUGWAY PRVG GRD
ATTN EN MM (JACK DAVIS)
DUGWAY UT 84022

1 FINISH THOMPSON INC
PRESIDENT CEO
H DAVID BOWES
921 GREENGARDEN RD
ERIE PA 16501-1591

1 KLEER FLO CO
PRESIDENT
WALLACE HILGREN
15151 TECHNOLOGY DR
EDEN PRAIRIE MN 55344

1 188 FG LGTM
4850 LEIGH AVE
ATTN SMS MITCHEL
FT SMITH AR 72903

1 89TH TRANS LGTM
3427 PENN AVE
ATTN SSGT C DOLLAR
ANDREWS AFB MD 20331-5005

1 ARMY PET CTR
ATTN PET READS DIV (WARD)
NEW CUMBERLAND PA 17070-5008

1 NAVAL WARFARE CTR
DEPT CODE SR 41
ATTN WALT KOEHLER
LAKEHURST NJ 08733

1 ALBERT MORALES
ATTN LDEE SALAC
KELLY AFB
SAN ANTONIO TX 78241

1 RALPH PHIPPS
NREA BRANCH
3040 MCCAWLEY AVE
QUANTICO VA 22134

1 TOM HACKNEY
PUBLIC WORKS DEPT
TRANS DIV CODE W80
NAVAL SURF WARFARE CTR
DAHLGREN VA 22448-5000

1 KANAS ARMY NATL GUARD
CSMS
ATTN D CRUMPTON
131 W 127TH ST
TOPEKA KS 66611-1159

1 GARY AKASAKI
DIR PUBLIC WORKS
ENVRL OFF USASCH
STOP 253
FT CHESTER HI 96858-5000

1 ERNIE BRANDT
DIR LOG MAINT DIV
FT RICHARDSON AK 99505

1 ADJ GENL PENN
ATTN SSCMO (REMMINGER)
BLDG 9 68
FT INDIANTOWN GAP
ANNVILLE PA 17003-5002

1 NATL GUARD BUREAU
ATTN NGB ZPF (LTC SMITH)
2500 ARMY PENTAGON
WASHINGTON DC 20310-25090

1 USPNFO
ATTN DSJ PC (REDHORSE)
BLDG 7100 CAMP ROBINSON
NORTH LITTLE ROCK AR 72118- 2200

1 MANNY RUYZ
49 CES CEV
550 TAVOSA AVE
HOLLOMAN AFB NM 88330-8450

20 MOB TECH CTR BELVOIR
ATTN AMSTA RBF
FORT BELVOIR, VA 22060

1 ISC-FT BELVOIR
ATTN ASQT FBR S (GRAPHICS)
FORT BELVOIR, VA 22060